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February 9, 1998

TO: Holders of the Fifth Edition of the Highway Design Manual

SUBJECT: Errata Sheets for the Highway Design Manual

The California Department of Transportation released the first metric Highway Design Manual as the Fifth Edition on July 1, 1995. Several errors have been identified and the corrections are contained in the attached errata sheets. Please replace the existing pages in your Highway Design Manual with the corrected pages attached. A summary of the corrections are as follows:

Table of Contents
Page x
- Topic 309 was erroneously titled "Clearances Clearances". It has been corrected to read "Clearances".

Table of Contents
Page xiii
- Topic 602 was erroneously titled "Structural Section Design Procedures Structural Section Design Procedures". It has been corrected to read "Structural Section Design Procedures".
- Topic 603 was erroneously titled "Traffic Data for Structural Section Design Traffic Data for Structural Section Design". It has been corrected to read "Traffic Data for Structural Section Design".

Index 21.2(1) "Sign Route Numbers"
Page 20-1
- The first paragraph incorrectly referenced Index 41.2. The correct reference is Index 42.2.

Index 201.6 "Stopping Sight Distance on Horizontal Curves"
Page 200-5
- The word "italicized" was misspelled as "italized".

Table 201.5A “Stopping Sight Distance on Sag Vertical Curves”
Page 200-10

- The “K” values at the top of the table were omitted.
- Some of the values contained in the column for “S=220 m” were incorrect.

Figure 201.6 “Stopping Sight Distance on Horizontal Curves”
Page 200-12

- In the table under “sight distance”, the symbol “*m*” was incorrectly used instead of “m” , the abbreviation for meters.

Table 201.6B “Stopping Sight Distance on Horizontal Curves”
Page 200-14

- The note at the top of the table referring to Section II was incorrect. The correct reference is to Table 201.1.

Figure 204.4 “Vertical Curves”
Page 200-25

- The first vertical curve formula was incorrect. The right side of the formula has been corrected so that it is divided by the number 800.

Figure 206.3(2) “Pavement Reductions”
Page 200-34

- The formula “VW” for taper length was incorrect. The correct formula has been corrected to “2/3 VW”.

Index 611.5(1) “PCCP Failure Types”
Page 600-59

- The misspelled word “plane-jointed” has been corrected to “plain jointed”.

Index 807.2 “Federal Highway Administration Hydraulic Publications”
Page 800-24

- HEC No. 15 was incorrectly titled. The word “Roadway” has been corrected to “Roadside”.

Figure 819.2C “Regional Flood-Frequency Equations”
Page 810-18

- In several locations through out this figure the notes referenced were incorrect.

Index 834.2(3) "Median Drainage"
Page 830-6

- Index 871.4 was incorrectly referenced. The correct reference is Index 871.3.

Index 854.3(2)(c) "Corrugated Steel Pipe and Pipe Arches"
Page 850-19

- The last bullet of this section incorrectly references Table 854.4B. The correct reference is Table 854.4C.

Index 903.5(3)(d) "Facilities and Features"
Page 900-9

- Index 608.8 was incorrectly referenced. The correct reference is Index 608.7(1).

Figure 1003.1E "Stopping Sight Distances for Crest Vertical Curves"
Page 1000-11

- The first formula at the top of the figure was incorrect. The number "25" has been corrected to read "2S".

If you identify any additional errors in the manual please contact your Geometric Reviewer or Karla Sutliff, Highway Design Manual Editor, at (916) 653-5107 or CALNET 8-453-5107.

Sincerely,

JERRY CHAMPA, Chief
Office of State Geometric Design Standards

Attachments

Table of Contents

Table of Contents

CHAPTER 20 DESIGNATION OF HIGHWAY ROUTES

Topic 21 - Highway Route Numbers

Index 21.1 - Legislative Route Numbers and Descriptions

The Legislature designates all State highway routes and assigns route numbers. The description and number of each route are contained in Chapter 2, Article 3 of the Streets and Highways Code. These route numbers are used for all administrative purposes.

The Legislature has stated its intent that the routes of the State Highway System serve the State's heavily traveled rural and urban corridors, that they connect the communities and regions of the State, and that they serve the State's economy by connecting centers of commerce, industry, agriculture, mineral wealth, and recreation.

A legislative route description generally runs south to north or west to east. To the extent possible, the number used on each route's guide signs is the same as the legislatively designated route number.

A specific location on any State highway is described by its kilometer post designation (formerly known as post miles). Kilometer posts (KP) start at the west or south county line and end at the east or north county line. Until the corporate database is complete, kilometer posts are determined by soft converting the post mile data. The conversion will be made by multiplying the post miles by 1.6093. All equations, prefixes and suffixes shall be retained. Post mile information is available in the State Highway Log and on post mile maps distributed by the Office of Office Engineer.

21.2 Sign Route Numbers

Each route in the State Highway System is given a unique number for identification and signed with distinctive numbered Interstate, U.S. or California State route shields to guide public travel. Route numbers used on one system are not duplicated on another system. Odd numbered routes are generally south to north and even numbered routes are generally west to east.

(1) *Interstate and Defense Highways.* The Interstate System is a network of freeways of national importance, created by Congress and constructed with Federal-aid Interstate System funds. Routes in the system are signed with the Interstate route shields (See Index 42.2 and Figure 21.1). Routes in one or two-digit numbers are north-south or east-west through routes. Routes in three-digit numbers, the first of which is odd, are interstate spur routes. For example, I-110 is a spur route off of I-10. Routes in three-digit numbers, the first of which is even, are loops through or belt routes around cities. I-805 in San Diego is an example of a loop off of I-5. The numbering of Interstate routes was developed by AASHTO with concurrence by the states.

   Renumbering of Interstate routes requires the approval of AASHTO to assure conformity with established numbering procedures. Such revisions also are a system action that must be approved by the Federal Highway Administrator.

   The Transportation Systems Information Program is responsible for processing requests for changes to the system to AASHTO and FHWA for their consideration.

(2) *United States Numbered Routes.* United States Numbered Routes are a network of State highways of statewide and national importance. These highways can be conventional roadways or freeways.

   The establishment of a U.S. number as a guide for interstate travel over certain roads has no connection with Federal control, any Federal-aid System, or Federal construction financing. The Executive Committee of AASHTO, with the concurrence of the states, has full authority for numbering U.S. routes.

   The Transportation Systems Information Program is responsible for processing requests for numbering U.S. routes to AASHTO for their consideration.

201.4 Stopping Sight Distance at Grade Crests

Figure 201.4 and Tables 201.4A & B show the relationship among length of vertical curve, design speed, and algebraic difference in grades. Any one factor can be determined when the other two are known.

201.5 Stopping Sight Distance at Grade Sags

From the formulas in Figure 201.5, the minimum length of vertical curve which provides headlight sight distance in grade sags for a given design speed can be obtained. When the stopping sight distance and algebraic grade difference are known, Table 201.5A gives the curve length. When the curve length and algebraic grade difference are known, Table 201.5B gives the sight distance.

If headlight sight distance is not obtainable at grade sags, lighting may be considered. The Project Development Coordinator and the Traffic Liaison Engineer shall be contacted to review proposed grade sag lighting to determine if such use is appropriate.

201.6 Stopping Sight Distance on Horizontal Curves

Where an object off the pavement such as a bridge pier, building, cut slope, or natural growth restricts sight distance, the minimum radius of curvature is determined by the stopping sight distance.

Stopping sight distance on horizontal curves is obtained from Figure 201.6 and Tables 201.6A & B. It is assumed that the driver's eye is 1070 mm above the center of the inside lane (inside with respect to curve) and the object is 150 mm high. The line of sight is assumed to intercept the view obstruction at the midpoint of the sight line and 600 mm above the center of the inside lane. This assumes there is little or no vertical curvature. The clear distance (*m*) is measured from the center of the inside lane to the obstruction. (Note that the clear distance "*m*" is italicized to distinguish it from the "m" used for meters.)

The general problem is to determine the required clear distance from centerline of inside lane to a retaining wall, bridge pier, abutment, cut slope, or other obstruction for a given design speed. Using radius of curvature and sight distance for the design speed, the formula in Figure 201.6 or Table 201.6A gives the clear distance (*m*) from centerline of inside lane to the obstruction.

When the radius of curvature and the clear distance to a fixed obstruction are known, the formula in Figure 201.6 and Table 201.6B gives the sight distance for these conditions.

See Index 101.1 for technical reductions in design speed caused by partial or momentary horizontal sight distance restrictions. See Index 203.2 for additional comments on glare screens.

Cuts may be widened where vegetation restricting horizontal sight distance is expected to grow on finished slopes. Widening is an economic trade-off that must be evaluated along with other options. See Index 902.2 for sight distance requirements on landscape projects.

201.7 Decision Sight Distance

At certain locations, sight distance greater than stopping sight distance is desirable to allow drivers time for decisions without making last minute erratic maneuvers (see Chapter III of "A Policy on Geometric Design of Highways and Streets," AASHTO, 1994).

<u>On freeways and expressways the decision sight distance values in Table 201.7 should be used at lane drops and at off-ramp noses to interchanges, branch connections, roadside rests, vista points, and inspection stations.</u>

Decision sight distance is measured using the 1070 mm eye height and 150 mm object height. See Index 504.2 for sight distance at secondary exits on a collector-distributor road.

Table 201.7
Decision Sight Distance

Design Speed (km/h)	Decision Sight Distance (m)
100 & under	315
101 - 110	335
111 - 120	375
121 - 130	415

Table 201.5A

Stopping Sight Distance on Sag Vertical Curves

Given "A" and "S"; Find "L"

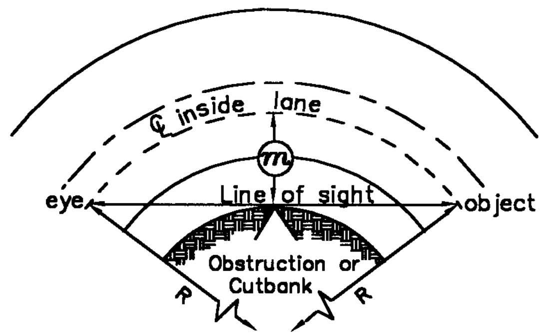
Double line represents S=L
L=Curve Length - meters
A=Algebraic grade difference - %
S=Sight distance - meters
V=Design speed - km/h
K=Distance in meters required to achieve a 1% change in grade.

A (%)	S=50 m V=40 km/h K=8 m L (m)	S=65 m V=50 K=12 m L (m)	S=85 m V=60 K=17 m L (m)	S=105 m V=70 K=23 m L (m)	S=130 m V=80 K=29 m L (m)	S=160 m V=90 K=38 m L (m)	S=190 m V=100 K=46 m L (m)	S=220 m V=110 K=54 m L (m)	S=255 m V=120 K=64 m L(m)	S=290 m V=130 K=74 m L (m)
1										
1.5										
2										
2.5					29	47	65	83	104	125
3					68	93	118	143	172	201
3.5				70	95	125	155	185	220	255
4			65	88	116	150	183	217	256	296
4.5			77	101	132	169	206	244	288	333
5		60	86	113	146	188	229	271	320	370
5.5		66	95	124	161	206	252	298	353	407
6		73	103	135	176	225	275	326	385	444
6.5		79	112	146	190	244	298	353	417	481
7		85	121	158	205	263	321	380	449	518
7.5	63	91	129	169	220	282	344	407	481	555
8	67	97	138	180	234	300	367	434	513	592
8.5	72	103	146	191	249	319	390	461	545	629
9	76	109	155	203	264	338	413	488	577	666
9.5	80	115	164	214	278	357	436	515	609	703
10	84	121	172	225	293	375	459	543	641	740
10.5	88	127	181	236	308	394	482	570	673	777
11	93	133	189	248	322	413	505	597	705	814
11.5	97	139	198	259	337	432	528	624	737	851
12	101	145	207	270	351	450	550	651	769	888
12.5	105	151	215	282	366	469	573	678	801	925
13	109	157	224	293	381	488	596	705	833	962
13.5	114	163	233	304	395	507	619	733	865	999
14	118	169	241	315	410	526	642	760	897	1036
14.5	122	175	250	327	425	544	665	787	929	1073
15	126	181	258	338	439	563	688	814	961	1109

Figure 201.6

Stopping Sight Distance on Horizontal Curves

Line of sight is 600 mm above ℄ inside lane at point of obstruction



S=SIGHT DISTANCE IN METERS.
R=RADIUS OF THE ℄ OF THE LANE NEAREST THE OBSTRUCTION IN METERS.
m=DISTANCE FROM ℄ OF THE LANE NEAREST THE OBSTRUCTION IN METERS.
V=DESIGN SPEED FOR "S" IN km/h.

DESIGN SPEED km/h	SIGHT DISTANCE m
50	65
60	85
70	105
80	130
90	160
100	190
110	220
120	255
130	290

Angle is expressed in degrees.

$$m = R\left[1-\cos\left(\frac{28.65S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R-m}{R}\right)\right]$$

- Formula applies only when "S" is equal to or less than length of curve.
- For sustained downgrades, see index 201.3.

See Table 201.6A (given "R" and "S", find "m") & Table 201.6B (given "R" and "m", find "S") for stopping sight distance on horizontal curves.

Table 201.6B

Stopping Sight Distance on Horizontal Curves

Lateral Clearance to Obstruction

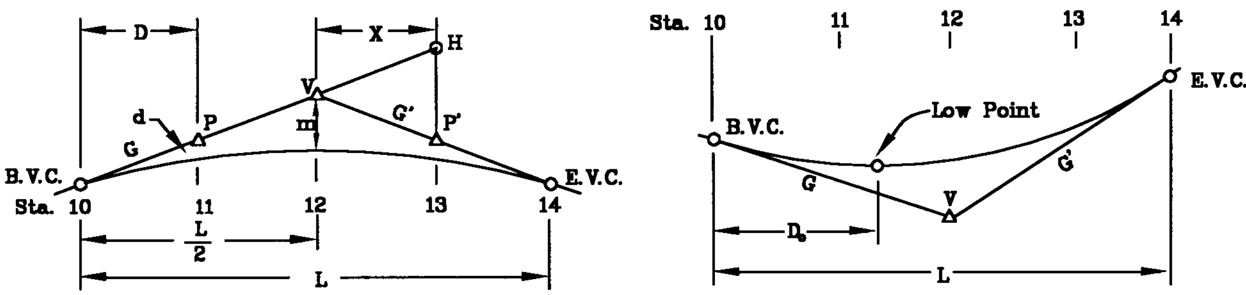
GIVEN "R" AND "m"; FIND "S"

Refer to Table 201.1 to determine design speed "V", after "S" is determined.

S=Sight distance - meters
R=Radius of CL lane - meters
m=Distance from CL lane - meters
V=Design speed - km/h, for "S"

R (m)	*m=* 2 meters S (m)	*m=* 3 meters S (m)	*m=* 4 meters S (m)	*m=* 5 meters S (m)	*m=* 6 meters S (m)	*m=* 7 meters S (m)	*m=* 8 meters S (m)	*m=* 9 meters S (m)	*m=* 10 meters S (m)	*m=* 11 meters S (m)
50	28	35	40	45	49	54	57	61	64	68
100	40	49	57	64	70	75	81	85	90	95
150	49	60	69	78	85	92	98	104	110	116
200	57	69	80	90	98	106	114	120	127	133
250	63	78	90	100	110	119	127	135	142	149
300	69	85	98	110	120	130	139	147	155	163
400	80	98	113	127	139	150	160	170	179	188
500	89	110	127	142	155	168	179	190	200	210
600	98	120	139	155	170	183	196	208	219	230
700	106	130	150	167	183	198	212	225	237	249
800	113	139	160	179	196	212	226	240	253	266
900	120	147	170	190	208	225	240	255	269	282
1000	127	155	179	200	219	237	253	269	283	297
1200	139	170	196	219	240	259	277	294	310	325
1400	150	183	212	237	259	280	299	318	335	351
1600	160	196	226	253	277	299	320	340	358	375
1800	170	208	240	268	294	318	340	360	380	398
2000	179	219	253	283	310	335	358	380	400	420
2500	200	245	283	316	346	374	400	424	447	469
3000	219	268	310	346	380	410	438	465	490	514

Figure 204.4
Vertical Curves



IN ANY VERTICAL CURVE:

(1) $m = \frac{(G'-G)L}{800}$

(2) $m = \frac{1}{2}\left(\frac{El.B.V.C.+El.E.V.C.}{2} - El.V\right)$

(3) $d = m\left(\frac{D}{L/2}\right)^2 = \frac{4m}{L^2}D^2$

(4) $d = \frac{D^2(G'-G)}{L200} = \frac{-D^2}{K200}$

(5) $X = \frac{100(H-P')}{(G'-G)}$

(6) $S = G - D\left(\frac{G-G'}{L}\right) = G - \frac{D}{K}$

(7) $D_o = \frac{LG}{G-G'}$

(8) $A = G - G'$

(9) $K = \frac{L}{A} = \frac{L}{G-G'}$

WHERE:

L = Length of curve – measured horizontally – meters.

G and G' = Grade rates – percent.

m = Middle ordinate – meters.

d = Correction from grade line to curve – meters

D = Distance from B.V.C. or E.V.C. to any point on curve – meters.

S = Slope of the tangent to the curve at any point – percent.

X = Distance, from P' to V – meters.

H = Elevation of grade G projected to station of P'

P and P' = Elevation on respective grades.

D_o = Distance to low or high point from extremity of curve – meters.

K = Distance in meters required to achieve a 1% change in grade.

NOTES:

A rising grade carries a plus sign, while a falling grade carries a minus sign.

Thus, in a crest vertical curve as above, G carries a plus sign and G' carries a minus sign when progressing in the direction of the stationing. When progessing in the opposite direction, G becomes a minus grade and G' a plus grade.

(3) *Lane Widening.* An increase in lane width can occur at short radius curves which are widened for truck off-tracking, at ramp terminals with large truck turning volumes, or when new construction matches existing roadways with narrow lane widths. Extensive transition lengths are not necessary as the widening does not restrict the drivers expectations. Transition tapers for these types of situations should be at 10:1.

(4) *Shoulder Widening.* Shoulder widening should normally be accomplished in a manner that provides a smooth transition, but can be accomplished without a taper if necessary.

206.3 Pavement Reductions

(1) *Through Lane Drops.* <u>When a lane is to be dropped, it should be done by tapering over a distance equal to 2/3WV, where W = Width of lane to be dropped and V = Design Speed</u>. In general, the transition should be on the right so that traffic merges to the left. Figure 206.2 provides several examples of acceptable lane drops at 4-lane to 2-lane transitions. The exception to using the 2/3WV criteria is for the lane drop/freeway merge movement on a branch connection which is accomplished using a 50:1 taper.

(2) *Ramp and Speed Change Lanes.* As shown in Figures 504.2A and 504.3C, the standard taper for a ramp merge into a through traffic lane is 50:1. Where ramp lanes are dropped prior to the merge with the through facility, the recommended taper is 50:1 for design speeds over 75 km/h, and the taper distance should be equal to 2/3 WV for speeds below 75 km/h.

The "Ramp Meter Design Guidelines" also provide information on recommended and minimum tapers for ramp lane merges. These guideline values are typically used in retrofit or restricted right-of-way situations, and are acceptable for the specific conditions stated in the guidelines.

Figure 405.9 shows the standard taper to be used for dropping an acceleration lane at a signalized intersection. This taper can also be used when transitioning median acceleration lanes.

Figures 405.2A, B and C show the recommended methods of transitioning pavement back into the median area on conventional highways after the elimination of left turn lanes.

(3) *Lane Reductions.* <u>At any location where lane widths are being reduced, the minimum length over which to accomplish the transition should be equal to 2/3WV</u>. See Index 504.6 for mainline lane reductions at interchanges.

(4) *Shoulder Reduction.* Shoulder reductions should typically occur over a length equal to WV/2. However, when shoulder widths are being reduced in conjunction with a lane addition or widening (as in Alt. A of Figure 504.3B), the shoulder reduction should be accomplished over the same distance as the addition or widening.

206.4 Temporary Freeway Transitions

It is highly desirable that the design standards for a temporary transition between the end of a freeway construction unit and an existing highway should not change abruptly from the freeway standards. Temporary freeway transitions must be reviewed by the Project Development Coordinator.

Topic 207 - Airway-Highway Clearances

207.1 Introduction

(1) *Objects Affecting Navigable Airspace.* An object is considered an obstruction to air navigation if any portion of that object is of a height greater than the approach and transverse surfaces extending outward and upward from the airport runway. These objects include overhead signs, light standards, moving vehicles on the highway and overcrossing structures, and equipment used during construction.

(2) *Reference.* The FAA has published regulations relative to clearance entitled, "Part 77, Federal Aviation Regulations" dated January, 1975. This is an approved reference to be used in conjunction with this manual.

- Rigid Pavement Maintenance Program (HM1B)

The Project Development Procedures Manual requires that all Project Scope Summary Reports (PSSRs) for roadway rehabilitation, reconstruction, and restoration projects include the latest Pavement Management System Inventory Report for the pavement segment included in the project limits.

611.3 Pavement Rehabilitation Project Development Procedures

Special project development procedures which include those mentioned in Index 611.1, are followed in the development and design of pavement rehabilitation projects in order to reduce the lag time between the recognition of pavement deterioration symptoms and construction of the project. These procedures are covered in the Project Development Procedures Manual.

611.4 General Pavement Structural Section Failure Types

Engineering judgment, based primarily on experience in pavement design, construction, materials, and maintenance, is required to identify pavement failure types and to determine the primary source of failure. With experience in these areas an observer can generally determine whether the failure is primarily in the pavement layer, the base and/or the subbase, or in the basement soil. Where there is no significant visual distortion in the riding surface, the failure can generally be assumed to be confined to the pavement layer.

In portland cement concrete pavement (PCCP) with basement soil problems, surface distortion is most commonly manifested in the form of uneven tipping of slabs or broken slab segments and sometimes by differential movement at joints. Step faulting at weakened plane transverse joints of uncracked slabs or at both transverse joints and intermediate transverse cracks, without uneven distortion, indicates that the problem is primarily confined to the structural section. A combination of the above conditions would indicate the problem is both in the structural section and basement soil.

In asphalt concrete pavement (ACP), base or subbase failure may be visually indicated by the rutting of the AC surface in the wheel paths or by alligator cracking of the AC. On the other hand, deep rutting may also indicate a lack of stability in the AC. Meandering cracks and differential settlement of the surface most likely indicates a subsurface problem.

There are many variables in materials and environment as well as other factors that affect the performance of pavement structural sections. This makes it impossible to develop hard and fast rules for the rehabilitation of pavements. Therefore, the PE should rely on the experience, judgment and guidance of engineers in pertinent functional engineering areas who are familiar with the design, construction, materials, and maintenance of pavement in the geographical area of the project. Deflection testing of ACP, coring of PCCP and other tests can be used to confirm judgments that are made.

The following discussion of pavement failure types for PCCP and ACP primarily includes those encountered in California on plain-jointed PCCP and on ACP. Brief definitions of these are also included in Topic 612. The failure type terminology shown below is generally the same as that included in the Pavement Management System Manual of Rating Instructions which is available in each district through the HA22 Program Advisor.

611.5 PCCP Failure Types

(1) *Faulting.* Also called step-faulting, this is a phenomenon that is common on California's plain jointed PCCP. This occurs primarily at transverse joints and at "working transverse cracks", as a result of slab pumping action that occurs with the passage of each heavy truck axle when the structural section is saturated. Pumping may continue for several weeks after a rainstorm.

A badly faulted pavement generally exhibits a history of shoulder distress adjacent to the edge of the traveled way, due primarily to the pumping of aggregate base fines from under the AC shoulder. Faulting, and the accompanying loss of full base support of the slab, generally precedes and is considered to be a major contributing factor to slab cracking and eventual breakup.

Watershed. The area drained by a stream or stream system.

Water Table. The surface of the groundwater below which the void spaces are completely saturated.

Waterway. That portion of a watercourse which is actually occupied by water.

Weephole. A hole in a wall, invert, apron, lining, or other solid structure to relieve the pressure of groundwater.

Weir. A low overflow dam or sill for measuring, diverting, or checking flow.

Topic 807 - Selected Drainage References

807.1 Introduction

Hydraulic and drainage related reference publications listed are grouped as to source.

807.2 Federal Highway Administration Hydraulic Publications

Copies of publications identified with an NTIS or GPO number may be ordered as follows:

- NTIS - Send a check to:

  National Technical Information Service
  5285 Port Royal Road
  Springfield, VA 22161
  (703) 487-4650

- GPO - Send a check to:

  Superintendent of Documents
  Government Printing Office
  Washington, D.C. 20402
  (202) 783-3238

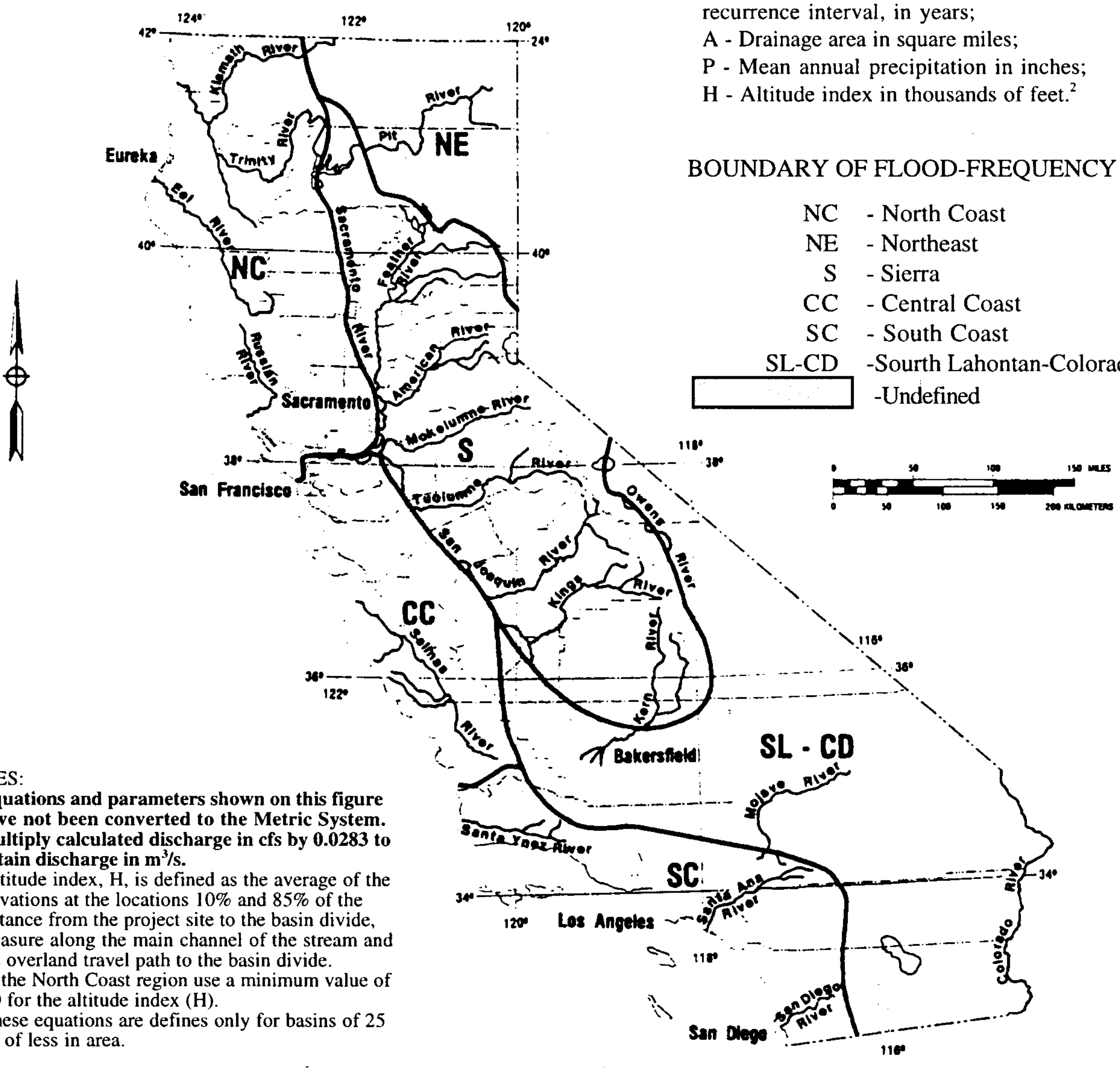
(1) Hydraulic Engineering Circulars (HEC).

HEC No.	Title	Date	FHWA # NTIS #
1	Selected Bibliography of Hydraulic and Hydrologic Subjects	1983	EPD-86-104 PB86-179256/AS
9	Debris-Control Structures	1971	EPD-86-106 PB86-179801/AS
10	Capacity Charts for the Hydraulic Design of Highway Culverts	1972	EPD-86-107 PB86-185691/AS
11	Design of Riprap Revetment	1989	IP-89-016 PB86-179793/AS
12	Drainage of Highway Pavements (GPO 050-001-00280-9)	1984	TS-84-202 PB84-215003/AS
14	Hydraulic Design of Energy Dissipators for Culverts and Channels	1983	EPD-86-110 PB86-180205/AS
15	Design of Roadside Channels with Flexible Linings	1988	IP-87-7 PB89-122584/AS
16	Addendum to Highways in the River Environment	1980	EPD-86-116 PB86-178852/AS
17	The Design of Encroachments on Flood Plains Using Risk Analysis	1981	EPD-86-112 PB86-182110/AS
18	Evaluating Scour at Bridges	1993	IP-90-017 PB91-198739
19	Hydrology	1984	IP-84-15 PB85-182954
20	Stream Stability at Highway Structures	1991	IP-90-014 PB91-198788
21	Bridge Deck Drainage Systems	1993	SA-92-010

Figure 819.2C
Regional Flood-Frequency Equations

NORTH COAST REGION[3]					NORTHEAST REGION[4]					SOUTH LAHONTAN-COLORADO DESERT REGION[4]			
Q_2	=3.52	$A^{0.90}$	$p^{0.89}$	$H^{-0.87}$	Q_2	=22	$A^{0.40}$			Q_2	=7.3	$A^{0.30}$	
Q_5	=5.04	$A^{0.89}$	$p^{0.91}$	$H^{-0.35}$	Q_5	=46	$A^{0.45}$			Q_5	=53.0	$A^{0.44}$	
Q_{10}	=6.21	$A^{0.88}$	$p^{0.93}$	$H^{-0.27}$	Q_{10}	=61	$A^{0.49}$			Q_{10}	=150	$A^{0.53}$	
Q_{25}	=7.64	$A^{0.87}$	$p^{0.94}$	$H^{-0.17}$	Q_{25}	=84	$A^{0.54}$			Q_{25}	=410.0	$A^{0.63}$	
Q_{50}	=8.57	$A^{0.87}$	$p^{0.96}$	$H^{-0.08}$	Q_{50}	=103	$A^{0.57}$			Q_{50}	=700.0	$A^{0.68}$	
Q_{100}	=9.23	$A^{0.87}$	$p^{0.97}$		Q_{100}	=125	$A^{0.59}$			Q_{100}	=1080.0	$A^{0.71}$	
SIERRA REGION					CENTRAL COAST REGION					SOUTH COAST REGION			
Q_2	=0.24	$A^{0.88}$	$p^{1.58}$	$H^{-0.80}$	Q_2	=0.0061	$A^{0.92}$	$p^{2.54}$	$H^{-1.10}$	Q_2	=0.14	$A^{0.72}$	$p^{1.62}$
Q_5	=1.20	$A^{0.82}$	$p^{1.37}$	$H^{-0.64}$	Q_5	=0.118	$A^{0.91}$	$p^{1.95}$	$H^{-0.79}$	Q_5	=0.40	$A^{0.77}$	$p^{1.69}$
Q_{10}	=2.63	$A^{0.80}$	$p^{1.25}$	$H^{-0.58}$	Q_{10}	=0.583	$A^{0.90}$	$p^{1.61}$	$H^{-0.64}$	Q_{10}	=0.63	$A^{0.79}$	$p^{1.75}$
Q_{25}	=6.55	$A^{0.79}$	$p^{1.12}$	$H^{-0.52}$	Q_{25}	=2.91	$A^{0.89}$	$p^{1.26}$	$H^{-0.50}$	Q_{25}	=1.10	$A^{0.81}$	$p^{1.81}$
Q_{50}	=10.4	$A^{0.78}$	$p^{1.06}$	$H^{-0.48}$	Q_{50}	=8.20	$A^{0.89}$	$p^{1.03}$	$H^{-0.41}$	Q_{50}	=1.50	$A^{0.82}$	$p^{1.85}$
Q_{100}	=15.7	$A^{0.77}$	$p^{1.02}$	$H^{-0.43}$	Q_{100}	=19.7	$A^{0.88}$	$p^{0.84}$	$H^{-0.33}$	Q_{100}	=1.95	$A^{0.83}$	$p^{1.87}$

Q - Peak discharge in CFS, subscript indicates recurrence interval, in years;
A - Drainage area in square miles;
P - Mean annual precipitation in inches;
H - Altitude index in thousands of feet.[2]



BOUNDARY OF FLOOD-FREQUENCY REGION

NC	- North Coast
NE	- Northeast
S	- Sierra
CC	- Central Coast
SC	- South Coast
SL-CD	-Sourth Lahontan-Colorado
	-Undefined

NOTES:
1. **Equations and parameters shown on this figure have not been converted to the Metric System. Multiply calculated discharge in cfs by 0.0283 to obtain discharge in m³/s.**
2. Altitude index, H, is defined as the average of the elevations at the locations 10% and 85% of the distance from the project site to the basin divide, measure along the main channel of the stream and the overland travel path to the basin divide.
3. In the North Coast region use a minimum value of 1.0 for the altitude index (H).
4. These equations are defines only for basins of 25 m² of less in area.

material. Cobbles, though effective for erosion control, are not satisfactory in a recovery area for out of control vehicles. See Topic 872 for further discussion on erosion protection and additional types of ditch linings. Erosion control references are given under Index 871.3.

(4) *Economy in Design.* Economy in median drainage can be achieved by locating inlets to utilize available nearby culverts or the collector system of a roadway drainage installation. The inlet capacity can be increased by placing it in a local depression. Use of slotted pipe at sag points where a local depression might be necessary may be an alternative solution to a grate catch basin.

834.3 Ditches and Gutters

(1) *Grade.* The flattest grade recommended for design is 0.25 percent for earth ditches and 0.12 percent for paved ditches.

(2) *Slope Ditches.* Slope ditches, sometimes called surface, brow, interception, or slope protection ditches, should be provided at the tops of cuts where it is necessary to intercept drainage from natural slopes inclined toward the highway.

When the grade of a slope ditch is steep enough that erosion would occur, the ditch should be paved. Refer to Table 862.2 for permissible velocities for unlined channels in various types of soil. When the ditch grade exceeds a 1:4 slope, a downdrain is advisable. Slope ditches may not be necessary where side slopes in favorable soils are flatter than 1:2 or where positive erosion control measures are to be instituted during construction.

(3) *Side Gutters.* These are triangular gutters adjoining the shoulder as shown in Figures 307.2 and 307.5. The main purpose of the one meter wide side gutter is to prevent runoff from the cut slopes on the high side of superelevation from flowing across the roadbeds. The use of side gutters in tangent alignment should be avoided where possible. Local drainage conditions, such as in snow areas, may require their use on either tangent or curved alignment in cut sections. In snow areas it may be necessary to increase the width of side gutters from 1 m to 2 m. The slope from the edge of the shoulder to the bottom of the gutter should be no steeper than 1:6. The structural section for paved side gutters should be adequate to support maintenance equipment loads.

(4) *Dikes.* Dikes placed adjoining the shoulder, as shown in Figures 307.2, 307.4, and 307.5 provide a paved triangular gutter within the shoulder area. For conditions governing their use, see Index 835.3.

(5) *Chart Solutions.* Charts for solutions to triangular channel flow problems are contained in FHWA Hydraulic Engineering Circular No. 12, "Drainage of Highway Pavements".

834.4 Overside Drains

The purpose of overside drains, sometimes called slope drains, is to protect slopes against erosion. They convey down the slope drainage which is collected from the roadbed, the tops of cuts, or from benches in cut or fill slopes. They may be pipes, flumes or paved spillways.

(1) *Spacing and Location.* The spacing and location of overside drains depend on the configuration of the ground, the highway profile, the quantity of flow and the limitations on flooding stated in Table 831.3. When possible, overside drains should be positioned at the lower end of cut sections. Diversion from one watershed to another should be avoided. If diversion becomes necessary, care should be used in the manner in which this diverted water is disposed.

Overside drains which would be conspicuous or placed in landscaped areas should be concealed by burial or other means.

(2) *Type and Requirement.* Following are details of various types of overside drains and requirements for their use:

(a) Pipe Downdrains. Metal pipes are adaptable to any slope. They should be used where side slopes are 1:4 or steeper. Long pipe downdrains should be anchored.

The minimum pipe diameter is 200 mm but large flows, debris, or long pipe installations may dictate a larger diameter.

The CULVERT3 (4-16-94) Computer Program, or subsequent upgrades, is also available to help designers estimate service life for various corrosive/ abrasive conditions. This program can be obtained from the District Hydraulics Engineer.

(2) *Strength Requirements*. The strength requirements for corrugated steel pipes and pipe arches, fabricated under acceptable methods contained in the Standard Specifications, are given in Tables 854.3B, C, D, & E.

(a) Design Standards.

- Corrugation Profiles - Corrugated steel pipe and pipe arches are available in 68 mm x 13 mm, 76 mm x 25 mm, and 125 mm x 25 mm profiles with helical corrugations, and 68 mm x 13 mm profiles with annular corrugations.
- Metal Thickness - Corrugated steel pipe and pipe arches are available in the thickness as indicated on Tables 854.3B, C, D & E. Where a maximum overfill is not listed on these tables, the pipe or arch size is not normally available in that thickness.
- Height of Fill - The allowable overfill heights for corrugated steel pipe and pipe arches for the various diameters or arch sizes and metal thickness are shown on Tables 854.3B, C, D & E.

(b) Basic Premise. To properly use the above mentioned tables, the designer should be aware of the premises on which the tables are based as well as their limitations. The design tables presuppose:

- That bedding and backfill satisfy the terms of the Standard Specifications, the conditions of cover, and pipe size required by the plans and the essentials of Index 829.2.
- That a small amount of settlement will occur under the culvert, equal in magnitude to that of the adjoining material outside the trench.

(c) Limitations. In using the tables, the following restrictions must be kept in mind.

- The values given for each size of pipe constitute the maximum height of overfill or cover over the pipe for the thickness of metal and kind of corrugation.
- The thickness shown is the structural minimum. Where abrasive conditions are anticipated, additional metal thickness or a paved invert as stated under Index 854.3(4) should be provided when required to fulfill the design service life requirements of Topic 852.
- Where needed, adequate provisions for corrosion resistance must be made to achieve the required design service life called for in the references mentioned herein.
- Table 854.3E shows the limit of heights of cover for corrugated steel pipe arches based on the supporting soil sustaining a bearing pressure varying between 240 and 405 kN/m^2. Table 854.4C shows similar values for corrugated aluminum pipe arches.

(d) Special Designs. If the height of overfill exceeds the tabular values, or if the foundation investigation reveals that the supporting soil will not develop the bearing pressure on which the overfill heights for pipe arches are based, a special design prepared by the Division of Structures is required.

(3) *Shapes*. Corrugated steel pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. For larger diameters, arch spans or special shapes, see Index 854.6.

(4) *Invert Protection*. Invert protection should be considered for corrugated steel culverts exposed to excessive wear from abrasive flows. Severe abrasion usually occurs when the flow velocity exceeds 4.5 m/s and contains a bedload. When severe abrasion is anticipated, special designs should be

All roads and parking areas should be designed to control vehicle traffic by the use of curbs or other barriers. The following comments relate to barriers:

(a) Service vehicles must be allowed access into the pedestrian area through rolled curb or a removable barrier.

(b) It is most desirable to have only one type of barrier throughout a development, although economics will often suggest the use of two or more types.

(c) Individuals with disabilities must be afforded easy access into the rest area without need to negotiate wheelchair or crutches over a curb. Rest areas shall be barrier free and accessible to all travelers. Accessibility means reasonable access to rest area facilities such as parking, picnic tables, walkways and comfort stations.

(d) Indiscriminate parking should be discouraged through the strategic placement of curbs and barriers.

The basic lengths and widths for parking spaces are as follows. See the Standard Plans for disabled accessible parking requirements.

	Length (m)	Width (m)
Auto	6	3
Trucks	21	4.5

Road widths at entrances and exits from parking spaces depend upon the parking angle and vehicle. Reference is made to the booklet, "A Guide to Safety Rest Areas for the National System of Interstate Highways," published by AASHTO. Truck turns should be used to verify road widths at entrances and exits from parking spaces. The minimum width for two-way roads is 9.6 m. See Index 608.7(1) for the design of roadside rest pavements.

(4) Comfort Facilities. The architect in the OSD will consult with the District Landscape Architect in regard to the design concept type and size of comfort station, and will perform the architectural design work. Buildings are to be well lighted, both interior and exterior. Comfort stations will be provided with flush-type toilet fixtures and a sewage disposal system.

Basically, the size of comfort stations will be determined by providing fixtures for each sex based upon parking capacity. For men, at least one-half of the total fixtures should be urinals. Lavatories should be provided on the basis of one per each two toilet fixtures. The OSD will determine the exact facilities to be provided. A minimum of 3 toilet fixtures including one that is handicap accessible for each sex will be provided. Diaper changing tables should be provided in each comfort station.

Maintenance forces must be provided a storage and utility area sufficient in size for equipment and supplies needed to maintain the rest area.

Drinking fountains with chilled water should be provided in conjunction with the comfort station. Drinking fountains without chilled water may be provided elsewhere in the rest area.

Heated-air drying units should be provided for the drying of hands. A heating system should be installed to eliminate freezing damage to plumbing and provide minimum human comfort levels.

Comfort stations should be located within 90 m and at no time exceed 135 m from the farthest parking space.

(5) Water Supply. Water systems will be designed to be adequate in quantity and quality for the projected use. The water supply system must be designed to handle the peak flow required to furnish water to fixtures in the comfort stations, plus the water necessary to irrigate the landscaped areas. A source of potable water must be one of the first considerations when selecting a site. Where there is no commercial source of water (nearby water district, city, etc.), then a source must be developed. The OSD will make all the necessary arrangements with the Office of Structure Materials (OSM) to drill a test hole (or holes) on the proposed site upon notification. They will drill the hole and furnish a complete log of the test hole including electric log. It can then be

Figure 1003.1E

Stopping Sight Distances for Crest Vertical Curves

$L = 2S - \frac{450}{A}$ when S > L

$L = \frac{AS^2}{450}$ when S < L

Height of cyclist eye - 1400 mm
Height of object - 100 mm

Double line represents S=L
L = Min. length of vertical curve - meters
A = Algebraic grade difference-%
S = Stopping sight distance - meters
V = Design speed km/h (Refer to Figure 1003.1D to determine “V”, after “S” is determined.)

GIVEN "A" AND "L"; FIND "S”

A (%)	L=50 m S (m)	L=100 m S (m)	L=150 m S (m)	L=200 m S (m)	L=250 m S (m)	L=300 m S (m)
4.5	75					
5	70	95				
5.5	66	90				
6	63	87				
6.5	60	83				
7	57	80	98			
7.5	55	77	95			
8	53	75	92			
8.5	51	73	89	103		
9	50	71	87	100		
9.5	49	69	84	97		
10	47	67	82	95		
10.5	46	65	80	93		
11	45	64	78	90		
11.5	44	63	77	88	99	
12	43	61	75	87	97	
12.5	42	60	73	85	95	
13	42	59	72	83	93	
13.5	41	58	71	82	91	
14	40	57	69	80	90	98
14.5	39	56	68	79	88	96
15	39	55	67	77	87	95